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general similitude to a peculiarly shaped fibula found in some ancient burial-places in France.

The President read the following paper on the construction of the Cassegrain Telescope :—

“ It is probably known to the Academy that an application has been made to Government, under the auspices of the Royal Society and the British Association, for the establishment of a large reflector in some convenient part of the British dominions, and its employment on a complete survey of the southern nebulae. In the course of the discussion which preceded this application, the construction of the telescope was an object of some importance, and I suggested that it might be desirable to try the Cassegrain : this was thought deserving of attention, and, in the hope that it may be acted on, I offer some rules for determining the dimensions of its parts, which will not be unimportant in so gigantic an experiment. They were investigated by me many years ago, when directing the arrangements of that which Mr. Grubb constructed for the Armagh Observatory. It is 15 inches aperture, and its performance is such as to justify an expectation that this form may be made of much greater magnitude.

“ The Cassegrain has been little used ; in fact, I know but of two, besides that referred to, which have been made of larger aperture than 6 inches : one of 18 inches by Lord Rosse, who, however, uses it as subsidiary to his larger telescopes, and has not given special attention to its improvement. The other was made by the elder Tulley about 1800 : it was 15 inches aperture, and 7 feet focus ; but it appears to have been indifferent ; for, according to the notes of William Walker (a competent judge) it ‘ showed Rigel like a shilling, and the companion was not seen at all.’ At that time, however, the proper method of supporting the great speculum was not known.

“ The cause of this neglect is perhaps the severe criticism of it which Newton made at the time of its invention : as compared to his telescope it is in some respects inferior, though on other grounds than those commonly assigned ; but in others it is superior. The defects are—

“ 1. In large instruments it is difficult to keep the magnifying power sufficiently low, the second image being five or six times as large as what is due to the focal length of the great speculum ; and this is essential, because the air is seldom so calm as to admit, with large apertures, of using powers proportional to those of lesser instruments.

“ 2. The rays have to pass thrice the length of the tube, while in the equivalent Newtonian it is twice the length : the tube is, however, shorter in the first instance, so that the actual spaces are as 1 : 1·28. As there is almost invariably a difference of temperature between the great speculum and the air in the tube, the latter is affected with eddies and currents, which cause indistinct vision in proportion to the quantity of disturbed medium which the rays traverse.

“ 3. The small mirror is larger than in the Newtonian, and therefore stops a little more of the central rays.

“ It was also objected by Newton that the field of view must be small, and that the reflection is more intense in the incidence of 45° on his small mirror, than at the perpendicular.

“ Of these the greater length of the light path is the only valid objection, and even this may probably be made less potent by establishing a downward current in the tube, or by apertures in it, to let the heated air escape freely. The magnifying power can be such as just to allow of the eye taking in the whole pencil, below which one cannot go without giving up part of the advantage of an instrument's size. The field can be quite as large as in the Newtonian. The loss of light by the difference of the small mirror is insignificant, the more so as the central rays are really the least valuable of all :

indeed even with achromatics we find that sometimes a difficult object is best seen when the central part of it is covered. The reflection at 45° *from metal* is, in fact, a little fainter than the perpendicular one, from which incidence its intensity decreases slowly till it becomes a minimum between 60° and 70° .

“ The advantages of the Cassegrain are :—

“ 1. The tube is shorter.

“ 2. The observer is near the ground ; he can easily be sheltered, and the eye-piece travels in a sphere of small radius : while with the Newtonian he requires a complex apparatus to support him, expensive and bulky.

“ 3. Any error of the large speculum can be corrected by figuring the small one to meet it. This, which was long since pointed out by Ramsden, is of much importance in large instruments ; for it is far easier, if the large speculum has not been perfectly figured, to let it abide, and work the other to it, having a few inches' aperture, and weighing a few pounds, than to dismount and move one of a couple of tons,—the more so as the control which is had over the process of polishing is very much greater in the first case. I say this from experience ; for the great speculum of the Armagh was made parabolic, that it might be used as a Newtonian, and the other was worked to correspond to it, as while spherical it gave but an indifferent definition.

“ 4. If the curvature of the second image be compared with the greater focal length of the ocular part which is required to give the same magnifying power, it will be found that the field is flatter with the single lens, or Huygenian eye-pieces, than in the Newtonian.

“ 5. The second image is so much larger than the primary one as to afford much facility for micromatic measurement.

“ 6. The adjustment of the specula is more easily verified.

“ These seem to me sufficient to invite the attention of any who are engaged in the construction of large telescopes to

this form, and to make it desirable that its principles should be developed more fully than is done by the existing treatises on Optics. Their formulæ do not include the magnitude of the emergent pencil, or the distance of distinct vision, the latter of which I noticed in a former communication as an element of magnifying power, and both of which are important in this inquiry.

“ The data are—

“(a) The eye must take in the whole pencil of rays which the great speculum received from the point which is examined, and which I assume to be on its axis. This diameter cannot exceed the maximum aperture of the pupil, which Sir W. Herschel determined to be two-tenths of an inch, or, taking the foot as unit, $\frac{1}{50}$.

“(b) The small mirror must receive the whole of the central pencil: if its magnitude be only sufficient for this it loses a little of the oblique pencils, but not enough to lessen the brightness materially. In a field of 10' the edge will be about one-ninth less bright than the centre.

“(c) The eye must be distant from the last image, real or virtual, by the quantity V , in order to have sharp vision. This distance was formerly assumed = 8 inches, but is less: the mean of my eyes, of my two assistants, and another individual, gives it = 6.42; Sir David Brewster makes it as low as 5, but I think it may be taken 6, or 6.5.

“(d) The first lens of the eye-piece (and the aperture in the great speculum) should have the same diameter as the small speculum for the lowest power; if less, it contracts the field of view; if larger, it lessens the effective surface of the great speculum. Hence the last ray is parallel to the axis.

“(e) The last image must be near the hinder surface of the great speculum box, in order to apply a micrometer. The distance between this and the surface of the speculum is about one-fifth of its aperture.

“ Let F, f', f'' be the focal lengths of the specula, and

the first lens, A , a , a' , their apertures; d and d' the distances of the first and second images from the second speculum; M the magnifying power, and θ the field of view: we have $a' = a$, and from

$$d = \frac{Fa}{A}.$$

The parallelism of the bounding ray gives

$$\theta = \cotan 1' \times \frac{ad}{d'} = \cotan 1' \times \frac{a^2}{Ad'}.$$

“The simplest ocular arrangement is to view the last image with the unaided eye. As, however, this telescope requires an eye-stop, or aperture, placed so as to transmit no light except what comes from the small mirror, a lens must be used to form an image of that at the stop. This lens will also form an image of the second image. Let ϕ be the distance of the second image behind the lens, u that of the third image in the same direction, u' that of the image of the small mirror, and x the section of the central pencil at the eye-stop:

$$u = \frac{\phi f'}{\phi + f'}; \quad u' = \frac{f'(d' - \phi)}{d' - \phi - f'}; \quad x = \frac{aV(\phi + f')}{df'};$$

$$M = \frac{A}{Va} \times \frac{\phi + f}{f} = \frac{A}{x}.$$

The condition of distinct vision gives

$$V = u' - u;$$

whence

$$\phi^2 - \phi(d' - 2f') = -f'^2 - f'd'.$$

Developing which, and omitting terms affected with $\frac{1}{d'^3}$, and upwards,

$$\phi = f' + \frac{4f'^2}{d'};$$

combining which with the value of x , we obtain a value of d' . This quantity is also in general

$$= F + \frac{A}{5} - \frac{Fa}{A} + \phi - u;$$

and as a , the aperture of the lens, is, according to the usual practice of opticians, $= \frac{1}{2} f'$, we derive

$$a \left(62.763 + \frac{F}{A} \right) - 0.18823 a^2 - 0.00394 a^3 = F + \frac{A}{5}.$$

The proposed reflector is to have $A = 4$ feet; and if we make $F = 9A$, which is Lord Rosse's proportion; we shall find $a = 0.5135$, or 6.16 inches.

“From this follow $f = 5.38$, $f' = 1.03$, $d = 4.62$, $d' = 32.74$; the distance of mirrors $= 31.38$, $M = 240$; and $\theta = 6'.92$. The field of view is too small, but the arrangement may be convenient from the sharpness of vision obtained with the single lens.

“From what has been stated as to the power of correcting the figure of the large speculum by the small one, it does not seem necessary that F should be so great; in the Armagh telescope it is only $7.5A$, and may be $8A$. On this supposition we find

$$a = 0.4641 = 5.57 \text{ inches.}$$

$$f = 4.24.$$

$$f' = 0.93. \quad M = 240.$$

$$d = 3.71. \quad \theta = 6'.25.$$

$$d' = 29.59.$$

$$\text{Distance of mirror} = 28.29.$$

The Huyghenian eye-piece is much to be preferred in this case. In it $3f'' = f'$, and the distance of the lenses $= \frac{2}{3}f'$. This combination, it must be remembered, is not achromatic unless the rays emerge parallel, but where the lenses are so large as they are here, the colour is scarcely perceived. Denoting, as before, by ϕ the distance of the second image from the field-glass; by u and z the distance of the two succeeding images from the lenses which form them; by u' and z' those of the images of the small speculum, the last of which is at the eye-stop, we have

$$u = \frac{\phi f'}{\phi + f'}; \quad z = \frac{f'}{3} \left(\frac{2f' - \phi}{2\phi - f'} \right); \quad u' = \frac{f' (d' - \phi)}{d' - \phi - f'};$$

$$z' = \frac{f'}{3} \left(\frac{d' - \phi + 2f'}{d' - \phi + f'} \right); \quad x = \frac{aV}{d'} + \frac{2\phi - f'}{f'}.$$

The condition of distinct vision gives $V = z + z'$, whence is derived

$$2\phi = d' + f' - \sqrt{\left(d'^2 - \frac{f'^2 d'}{V} \right)}, \text{ or nearly } = f' + f'^2 + \frac{f'^4}{2d'};$$

using which in x , and setting $2a$ for x , we have

$$d'^2 - 60a^2 d' = 120a^4.$$

Equating the value of d' given by this to its general one, we have

$$\left(\frac{F}{A} - \frac{1}{3} \right) a + 60.790a^2 - 0.63151a^3 + 0.43461a^4 - 0.29979a^5 + \&c.$$

$$= F + \frac{A}{5}.$$

With $F = 9A = 36$, this gives

$$a = 0.7115 = 8.54 \text{ inches.}$$

$$f = 8.02.$$

$$f' = 1.423. \quad M = 240.$$

$$d = 6.40. \quad \theta = 13'.88.$$

$$d' = 31.34.$$

$$\text{Distance of mirror} = 29.60.$$

With $F = 8A = 32$ we have

$$a = 0.6760 = 8.11 \text{ inches.}$$

$$f = 6.68.$$

$$f' = 1.35. \quad M = 240.$$

$$d = 5.41. \quad \theta = 13'.88.$$

$$d' = 28.30.$$

$$\text{Distance of mirror} = 26.59.$$

In these the field is as large as can be obtained with this power in any telescope without a triple eye-glass.

“ The Newtonian does not require the same exactness in its arrangement, but I add the formula for it. The data are, that the image must be outside the tube, distant from the axes $\frac{1}{2}A + m + \phi - u$; m may be neglected if the tube be iron; the eye must receive the whole pencil; and the eye-stop, placed at the image of the large speculum, must be V distant from the last image of the object. With a single lens, calling $2b$ the axis minor of the small speculum,

$$u = \frac{f'\phi}{f' - \phi}; \quad u' = \frac{f'(F + \phi)}{F + f' + \phi}; \quad x = \frac{AV(f' - \phi)}{Ff'};$$

$$2b = \frac{A}{F} \left(\frac{1}{2}A \right); \quad \theta = \cotan 1' \times \frac{1}{F} \left(a + \frac{\phi(2b - a)}{\frac{A}{2} - b - \phi} \right).$$

The condition of vision is

$$V = u + u',$$

whence

$$\phi^2 + F\phi = f'(F + f') - f'^2 \frac{(F + 2f')}{V};$$

and the expression of x gives

$$\phi = f' \left(1 - \frac{F}{6AV} \right),$$

whence

$$f'^2 + \frac{f'}{4} \left(2F - \frac{F}{15A} + \frac{F^2}{900A^2} \right) = \frac{F^2}{120};$$

which for $F = 36 = 9A$ gives

$$2b = 0.2222 = 2.67 \text{ inches.}$$

$$f' = 0.1575 = 1.89 \quad ,,$$

$$M = 240.$$

$$\theta = 8.37.$$

For the Huyghenian the formulæ given for the Cassegrain apply, changing d into F , and a , when it belongs to the small speculum, to A :

$$2b = \frac{A}{F} \left(\frac{A}{2} + \phi - u \right); \quad \theta = \frac{\cotan 1'}{F} \left(a - \frac{\phi(2b - a)}{\frac{A}{2} - b - \phi} \right)$$

We thus obtain

$$f'^3 + 2Ff' = \frac{F^2}{15A}; \quad \phi = \frac{f'}{2} \left(1 + \frac{F}{30A} \right);$$

whence

$$2b = 0.2308 = 2.77 \text{ inches.}$$

$$f' = 0.2998 = 3.60 \quad ,,$$

$$M = 240.$$

$$\theta = 13.46.$$

“The field here is nearly the same as in the Cassegrain; with the single lens it is something larger, which arises from that lens acting differently in the two cases, in that it diminishes the image, and therefore requires an increased value of d' .”

DECEMBER 12TH, 1853.

THOMAS ROMNEY ROBINSON, D. D., PRESIDENT,
in the Chair.

THE REV. H. LLOYD, D. D., read a supplemental note “on the magnetic influence of the moon.”

In a previous communication* the author had shown, from a discussion of the observations made at the Magnetical Observatory of Dublin, that the magnetic declination was subject to a small periodical variation dependent upon the moon's hour-angle, the north pole of the magnet deviating twice to the east, and twice to the west, in the course of the lunar day. It was, of course, to be expected that a similar variation would be found to affect the other two magnetic elements. In order to trace its existence, and to determine its law, in the case of the horizontal component of the magnetic intensity, the author

* Proceedings, May 9, 1853.